

Ionospheric calibration for K-band celestial reference frames

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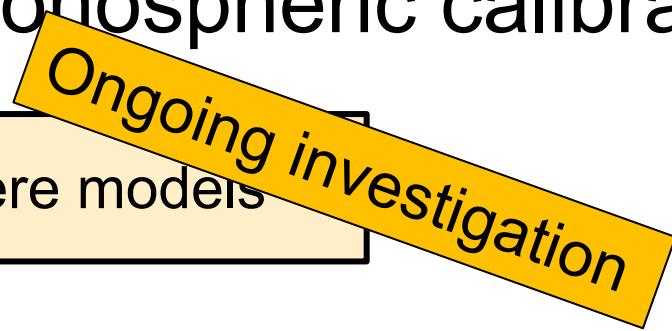
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Introduction

- CRF based on K-band (24 GHz) part of ICRF3
 - VLBA + Hobart-HartRAO
 - Mostly 2 Gbps data rate, testing 4 Gbps
 - Posters by De Witt et al, Krasna et al, and talk by Le Bail et al
- + Advantage: less source structure compared to S/X
 - S/X CRFs limited by a 20-30 μ as source structure noise floor
- Disadvantage: single-frequency observations
 - About 95% of the K-band ionospheric effect needs to be corrected to reach S/X noise level

Accuracy depends on external ionospheric calibration

How to improve the ionospheric calibration?

- 
1. Improvements in ionosphere models
 2. Improvements from better model coverage of VLBI stations

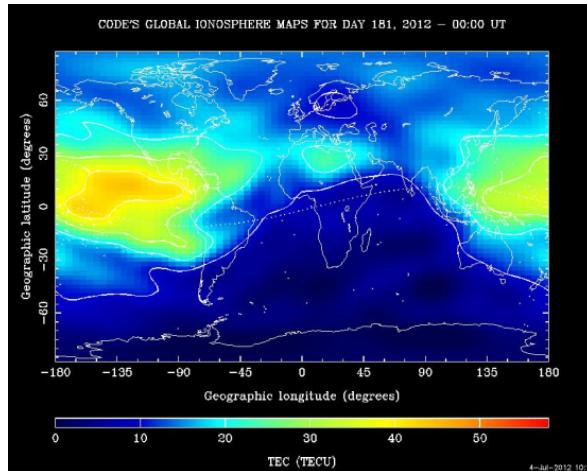
Background – ionospheric corrections

- Dual-frequency observations: ionosphere-free linear combination
- Single-frequency observations: ionospheric delay determined from ionosphere models
- Simplest models: two-dimensional, single thin-layer approximation
- Approach to determine ionospheric corrections:
 1. Determination of the ionospheric pierce point (IPP)
 2. Vertical total electron content (VTEC) at IPP from model
 3. VTEC to STEC (Slant TEC) using a mapping function
 4. Ionospheric delay from STEC

$$\tau_{\text{iono}} = \frac{40.3}{cf^2} \text{ STEC}$$

Global Ionospheric Maps (GIMs)

- International GNSS Service (IGS) operationally provides 2-dimensional maps of VTEC and VTEC RMS
 - Based on a combination of GIMs from individual analysis centers
 - Temporal resolution: 2 hours
 - Spatial resolution: 5 deg (lon) x 2.5 deg (lat)
 - Stated uncertainty 2-8 TEC units (TECu)

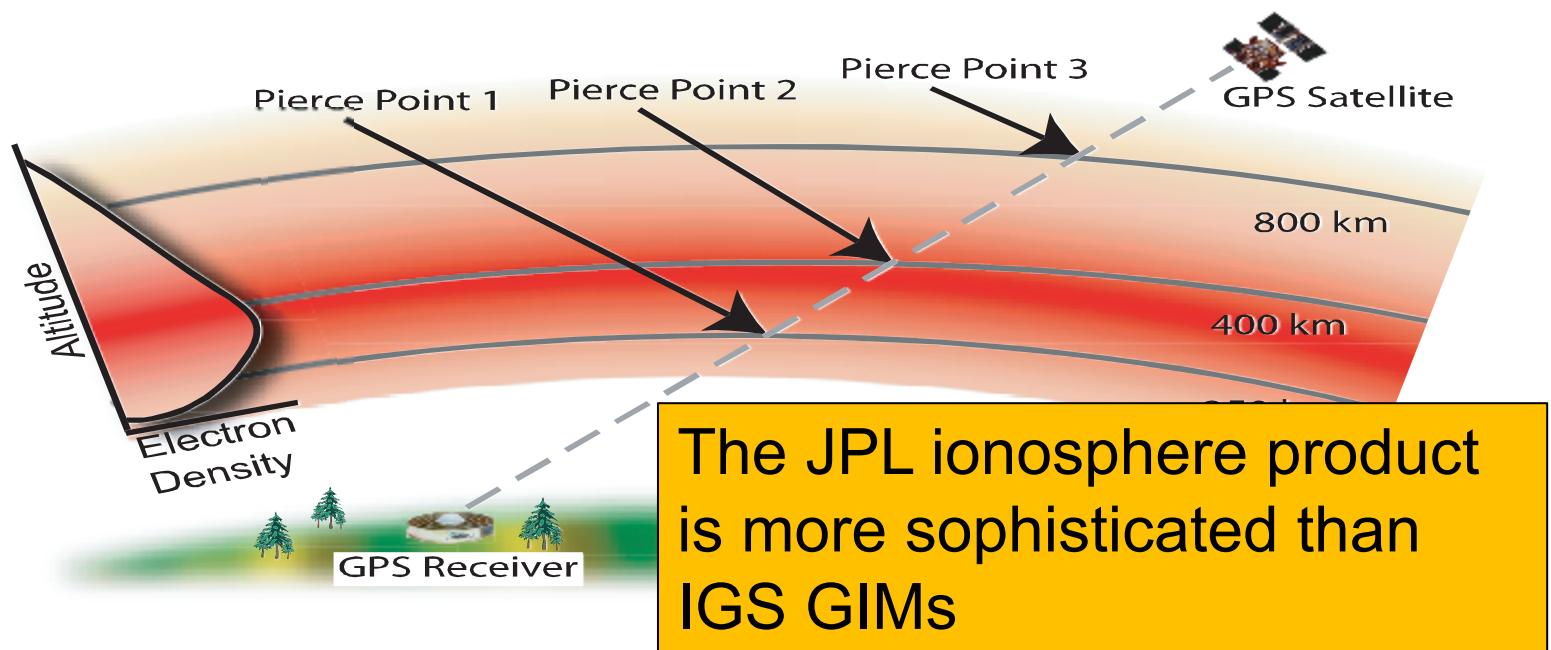


1 TECu \approx 0.7 mm delay in K-band

IGS GIMs were used
for the K-band ICRF3

JPL ionosphere product

- JPL computes ionosphere models from GNSS data assuming 3 horizontal layers instead of a single one
 - Temporal resolution: **15 minutes**
 - Spatial resolution: 330 base functions per layer instead of grid



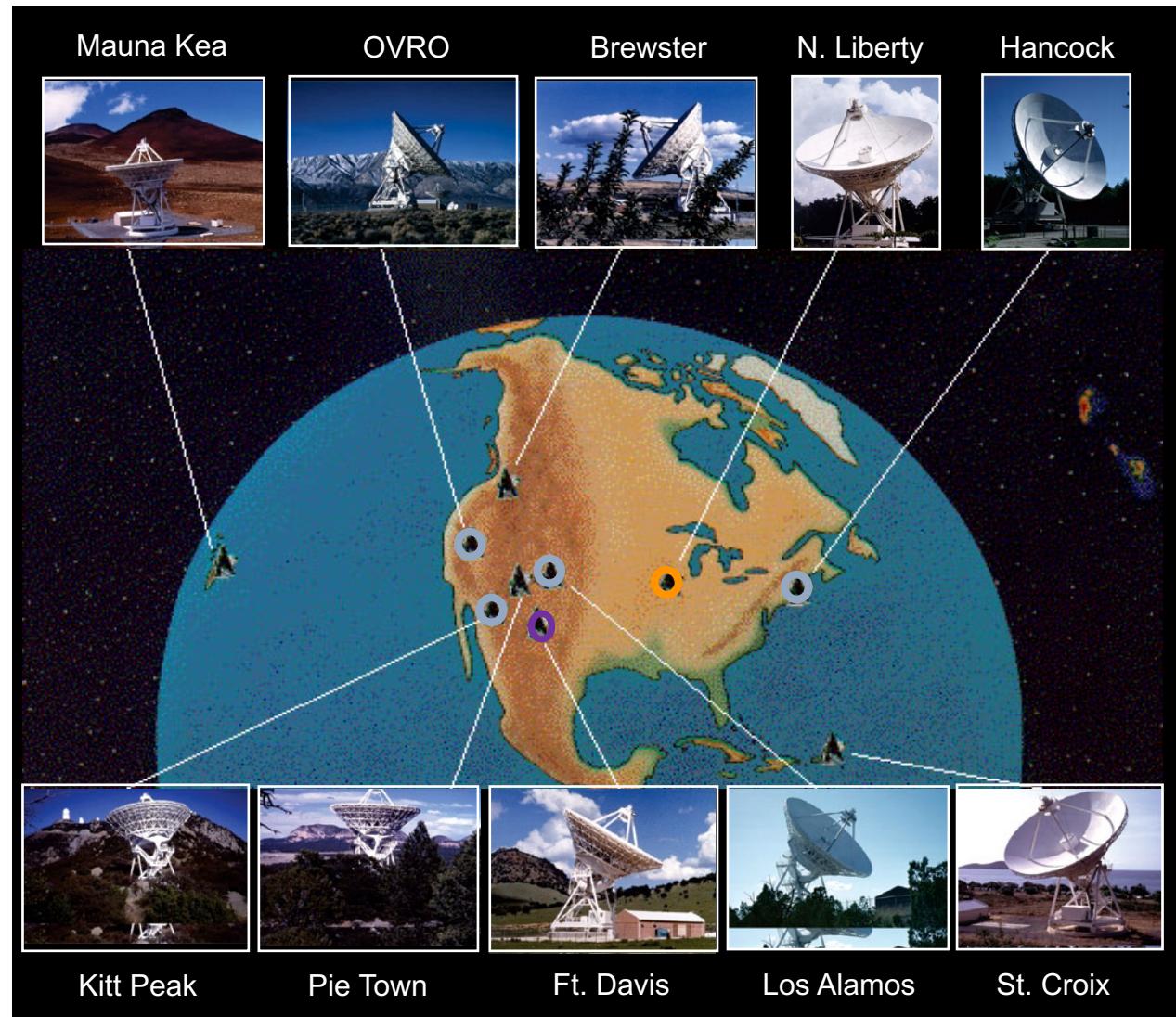
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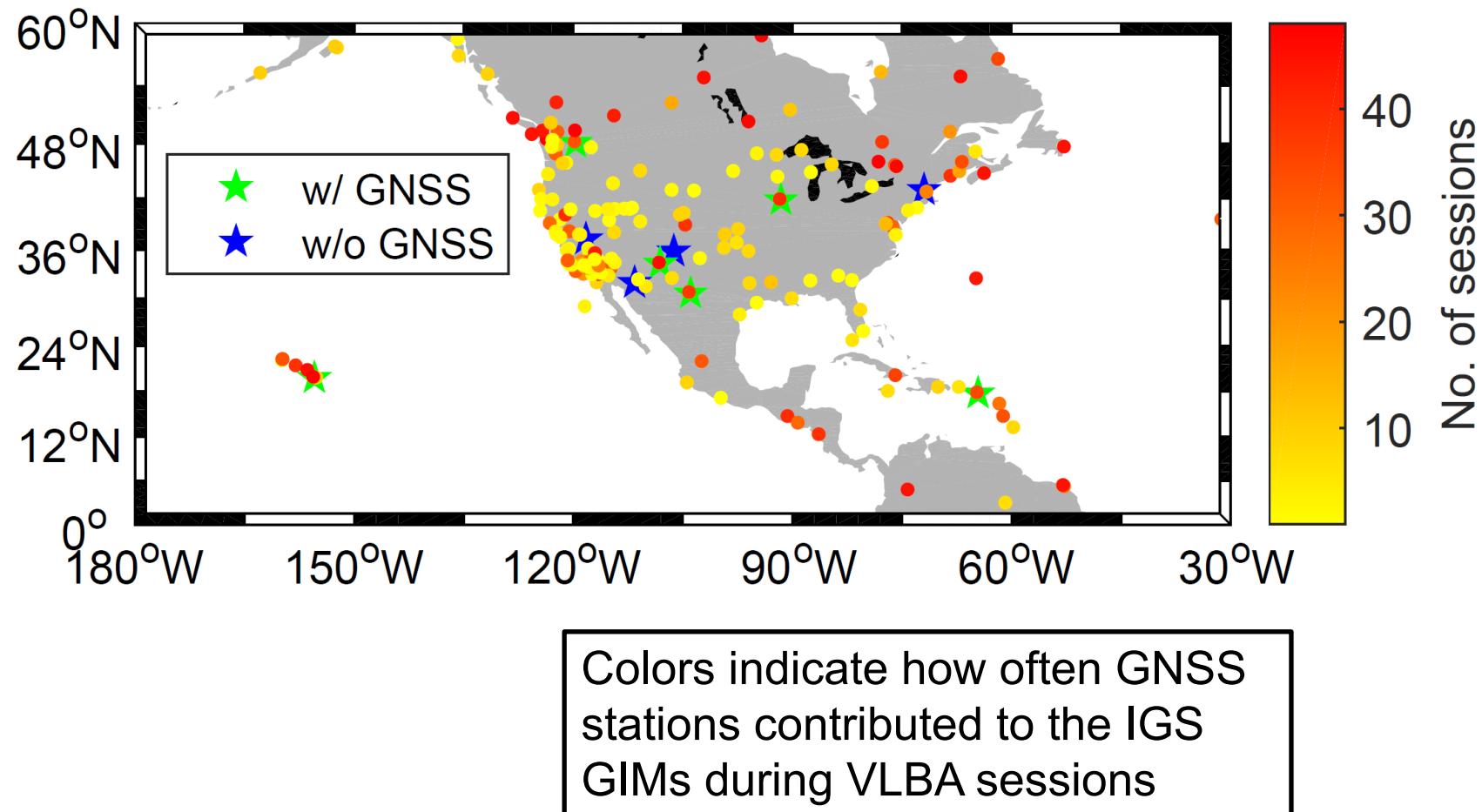
GNSS antennas at VLBA sites

Very Large Baseline Array <http://www.vlba.nrao.edu/>

- Coverage gaps:
 - HN missing
 - OV missing
 - KP missing
 - LA missing
- NL **broken** since Nov 2018
- FD offset 8 km



IGS GIM station distribution

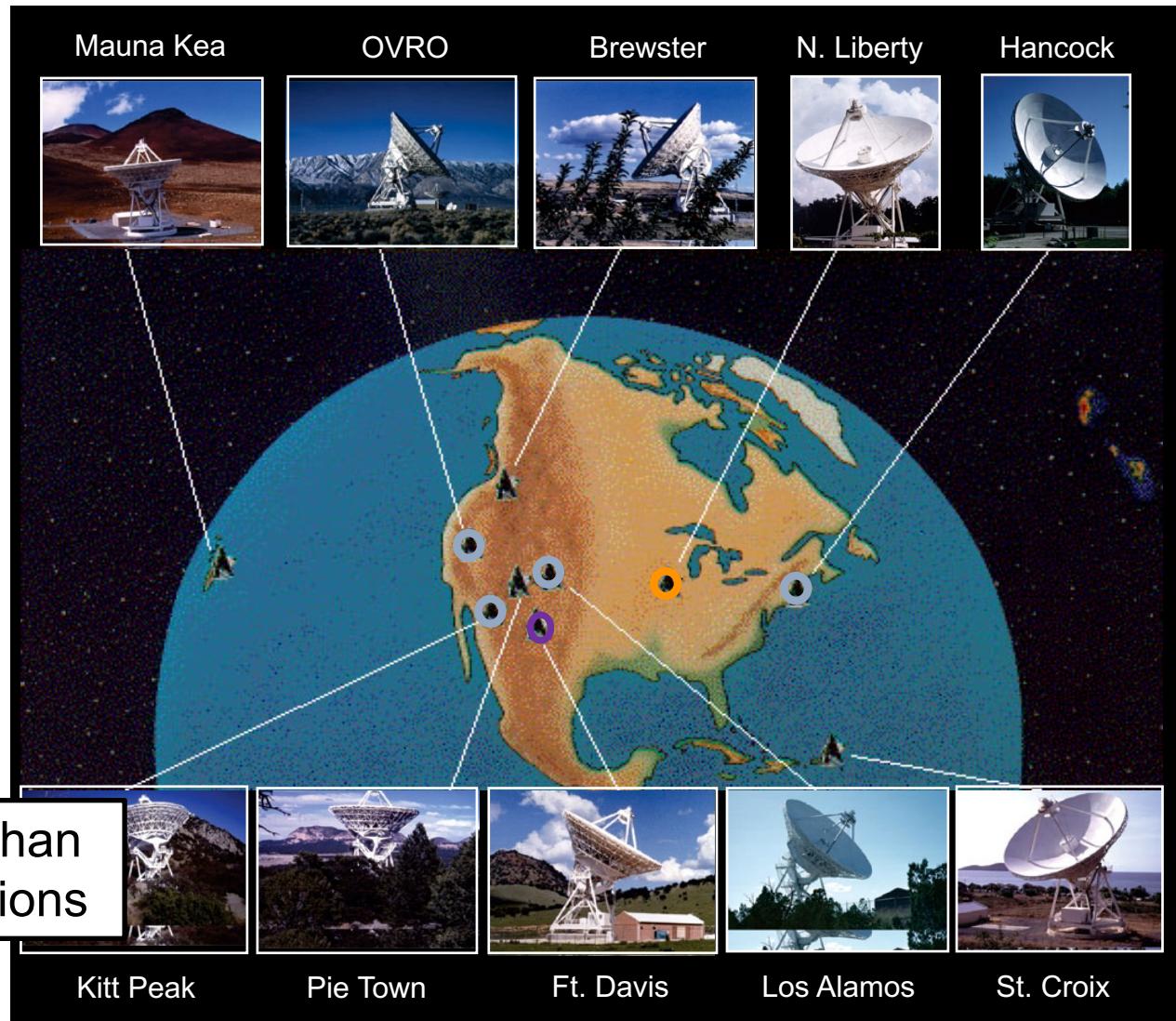


Distances to active* IGS GIM stations

Very Large Baseline Array <http://www.vlba.nrao.edu/>

- HN 344 km
- OV 206 km
- KP 343 km
- LA 236 km

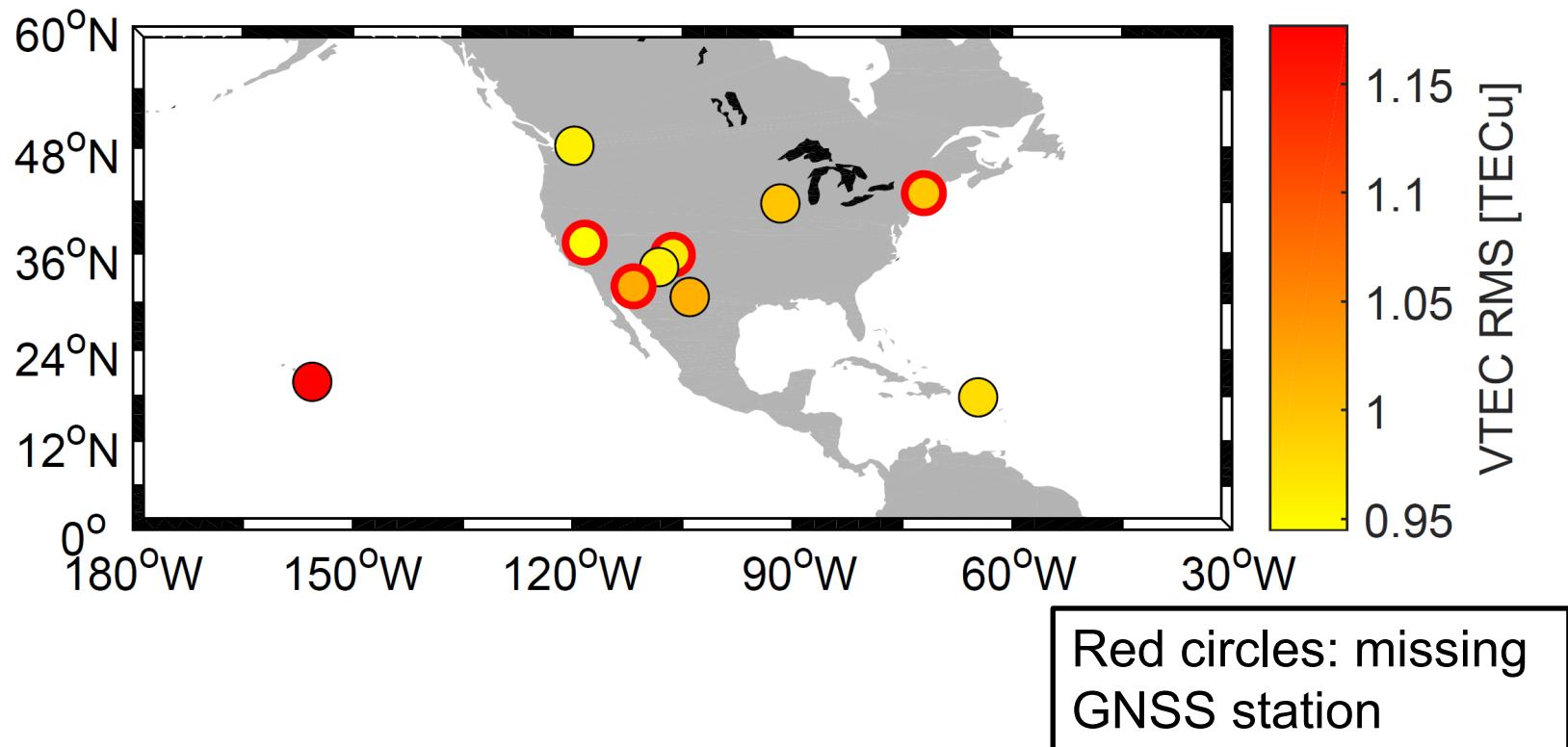
- NL 999 km
since Nov 2018
- FD 8 km



*contributed to more than half of the VLBA sessions

GIM VTEC RMS for VLBA sites

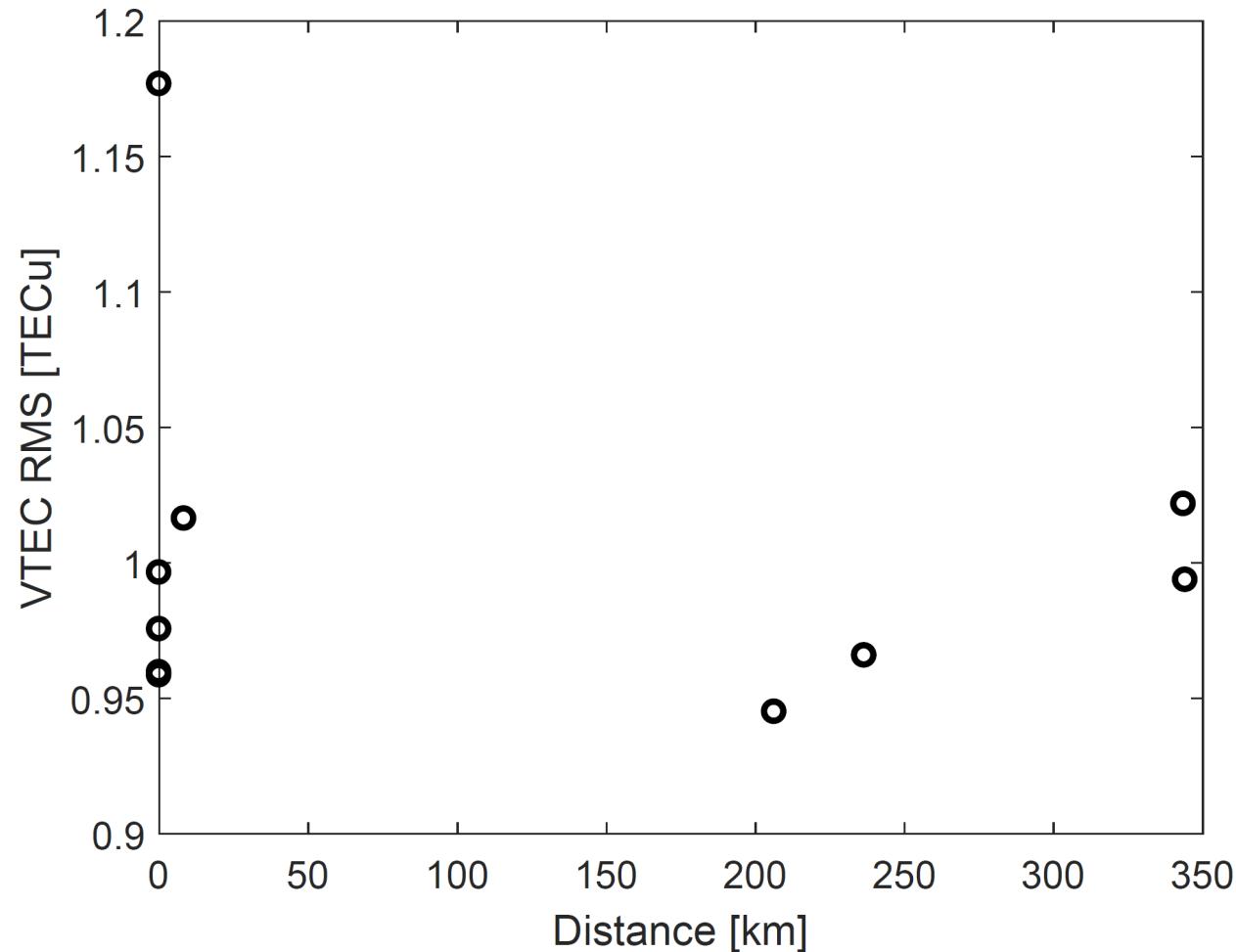
- Extracted from IGS GIMs
- Averaged over K-band VLBA sessions



GIM VTEC RMS for VLBA sites

Station name	GNSS on site	GNSS distance	VTEC RMS [TECu]	K-band delay RMS [mm]
HN-VLBA	0	344.267	0.99	0.72
LA-VLBA	0	236.585	0.97	0.70
NL-VLBA	0 / 1	0.068 / 998.799	1.00	0.73
OV-VLBA	0	206.384	0.94	0.69
PIETOWN	1	0.062	0.96	0.70
MK-VLBA	1	0.089	1.18	0.86
SC-VLBA	1	0.083	0.98	0.71
BR-VLBA	1	0.059	0.96	0.70
KP-VLBA	0	343.677	1.02	0.74
FD-VLBA	1	8.418	1.02	0.74

VTEC RMS vs. GNSS station distance

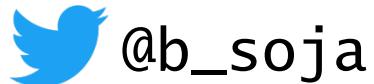


Conclusions

- **K-band** VLBI data has the potential to improve the CRF due to less source structure than S/X
- K-CRF accuracy depends on **ionospheric calibration**
- Currently working on implementing ionospheric calibrations with **15 min** temporal resolution
- Four VLBA sites **without GNSS stations** actively contributing to IGS GIMs
 - No significant degradation detected in the VTEC precision for these sites
 - Could be worse for N. Liberty (1000 km from active GNSS station)

Thanks for your attention!

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Acknowledgements

B. Soja's research was supported by an appointment to the NASA Postdoctoral Program at the NASA Jet Propulsion Laboratory, administered by Universities Space Research Association under contract with NASA.